THE GENESIS OF A TROPICAL CYCLONE

By FRANKLIN G. TINGLEY

Foreword, by Willis E. Hurd.—After Mr. Tingley's death there was found in his desk the substance of the following article. It was preeminently true of its writer that he exercised a great amount of caution in the preparation of any text out of the routine for publication, with characteristic gentleness and shyness preferring to withhold its appearance in type until his ground for statements was completely laid out, solid, and satisfactory. Originally intended for publication in the MONTHLY WEATHER REVIEW, in conjunction with some related notations and analyses prepared by L. T. Chapel, of the Hydrographic Office at Cristobal, the Genesis of a Tropical Cyclone was apparently in the main complete, though it required some rearrangements and amplifications. These changes have been undertaken sympathetically by the writer of this foreword, with the feeling and hope that they would not have been unacceptable to his former division chief, from whom, in connection with his own studies and writings, he had always received the most sympathetic and helpful consideration.

The locality and some of its meteorological features.—About the middle of October, 1926, a cyclone of great importance formed in the southwestern part of the Caribbean Sea, where that body of water extends southward to the Isthmus of Panama. This extension is in the form of a large embayment extending some 700 or 800 miles southwestward from the main body of the Caribbean and having at its southern extremity the Mosquito Gulf on the Central American side and the Gulf of Darien bordering on the South American mainland. This part of the Caribbean lies between the region of the northeast trade winds of the Atlantic and that of the south to southwest winds of the extreme southeastern North Pacific. It is a zone marked by a large percentage of calms, the 5° square bounded by the tenth and fifteenth parallels and the eightieth and eighty-fifth meridians, in which the cyclone originated, having a percentage of 22. The bordering 5° squares show percentages as follows: North, 14; east, 12; south, 25; west, 37. The frequency of calms, as well probably as the existence of oppositely directed winds on either side, makes it a region favorable for the formation of cyclones. Indeed, one may well ask the question, Why do cyclones not form here in greater numbers?

While the meteorological features of the region, including the Isthmus of Panama and adjacent territory, have been very fully studied in recent years, it is desired to emphasize the annual changes that occur in the wind régime at the Isthmus as shown by the records of the Colon Observatory. An article by L. T. Chapel, of the Hydrographic Office, Cristobal, published in the MONTHLY WEATHER REVIEW for December, 1927, (1) deals very fully with wind conditions in the Panama area, and two diagrams which appeared in that article show the annual march of wind frequency and velocity at Colon and also at Cape Mala, 113 miles to the southward.

Inasmuch as something like three-fifths of the tropical cyclones that form in the western Caribbean occur in October and November, the behavior of the winds at this season of the year has a special significance. The diagrams referred to show clearly the decline in the frequency of northerly winds, which reach a minimum in October, and the concurrent decrease in velocity. Data are not adequate to show how far northward over the waters of the Caribbean this seasonal reversal of condition extends, but it appears likely that the area embraced includes that in which the majority, if not all, of the autumn hurricanes of this region have their origin.

In the general region of the western and southwestern Caribbean some 54 cyclones have had their origin in the past 44 years, or during the period 1887–1930, of which number 23 are known to have attained hurricane intensity. Out of the total some 22 have probably formed in approximately the same region as the one particularly under consideration, namely, that of 1926. Information, however, is not clear on this point in every instance. Of the extreme southwestern group, 10 occurred in October, 5 in November, 4 in September, 2 in June, and 1 in July.

Another preliminary meteorological fact is here well worth noting. Mitchell (2) has shown that tropical cyclones of the West Indies and North Atlantic Ocean develop principally in two general regions, one of which is the western Caribbean Sea; the other, the eastern part of the ocean near the Cape Verde Islands. In these localities, especially during specific periods, doldrum conditions in the North Atlantic are most fully developed. The existing records, extending now over many years, fail to show conclusively that any tropical cyclone has originated in the eastern part of the Caribbean Sea or adjacent areas of the Atlantic, and in this connection it may be explained that the tracks of tropical cyclones as depicted on the various charts start in many instances where the storm was first observed, perhaps fully developed, and that in some cases at least it is impossible to track the cyclone to its place of origin owing to lack of observations.

Ship and land observations in the southwestern Caribbean.—A distinguishing feature of this specific region, and one that merits the attention of students, is its favorable situation for the securing of observations. It is on this account one of the best suited of all bodies of water for the study of embryonic tropical cyclones at the present time, since many more observations are potentially available from this part of the Caribbean Sea than from almost any other originating locality. In recent years the greater part of the growth of shipping here, and therefore of potential weather observations, is, of course, due to the construction of the Panama Canal, which was opened to traffic in 1914. But a part also results from the development of the tropical-fruit industry and other South and Central American resources.

A circumstance that makes the early history of the 1926 cyclone of more than ordinary interest is the unusually full number of vessel observations available for the region and period of formation, as well as some highly interesting observations from near-by coastal stations. While even this number is not so numerous and well placed for study as could be wished, nevertheless it constitutes the best series on record covering the incipient stages of a tropical cyclone in these, if not in other, waters.

The land observations comprise those from the first-order stations at Colon and Balboa Heights, Panama Canal Zone, and Bluefields, Nicaragua. Compilations of wind and barometric data for the first two stations for the period October 13–20, 1926, kindly prepared by R. Z. Kirkpatrick, chief of surveys, the Panama Canal, appear herewith as Tables 1 and 2. Data for Bluefields for October 12 to 18, inclusive (7 a. m. and 7 p. m., seventy-fifth meridian time), are shown in Table 4. A record of pilot-balloon flights at the United States naval air station at Coco Solo, Canal Zone, near Colon, distant about 150 miles from the point of origin of the hurricane, appears in Table 3.

Formation and development of the storm.—The history of the hurricane in question of 1926 may be said to have

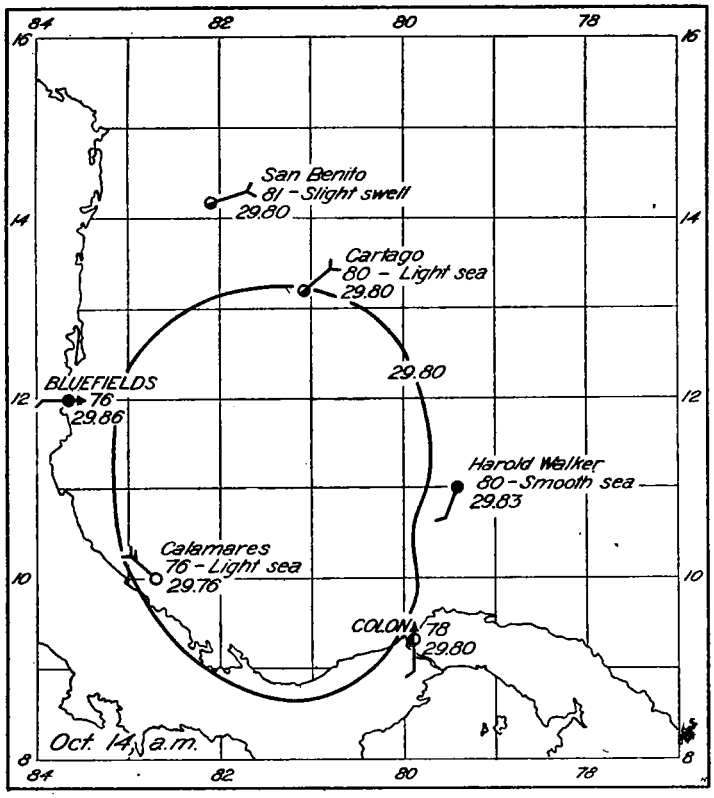

FIGURE 1.—Pressure and wind conditions at 7 a. m. of October 14, 1926

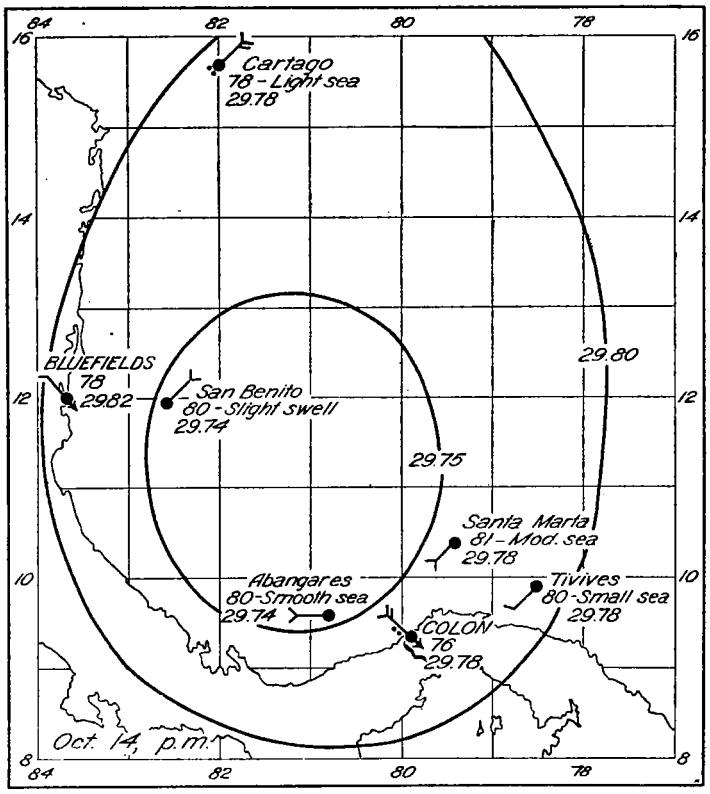

FIGURE 2.—Pressure and wind conditions at 7 p. m. of October 14, 1926

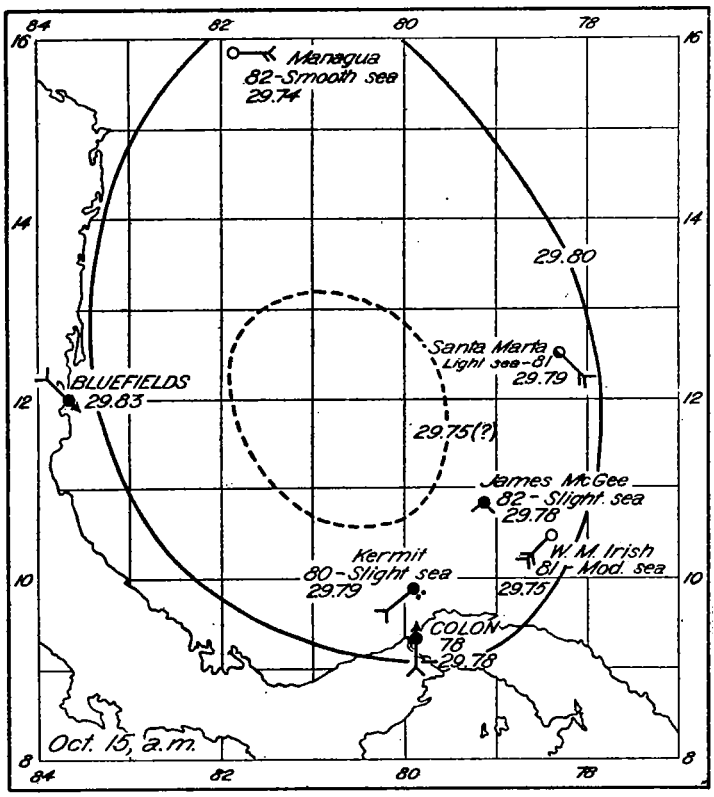

FIGURE 3.—Pressure and wind conditions at 7 a. m. of October 15, 1926

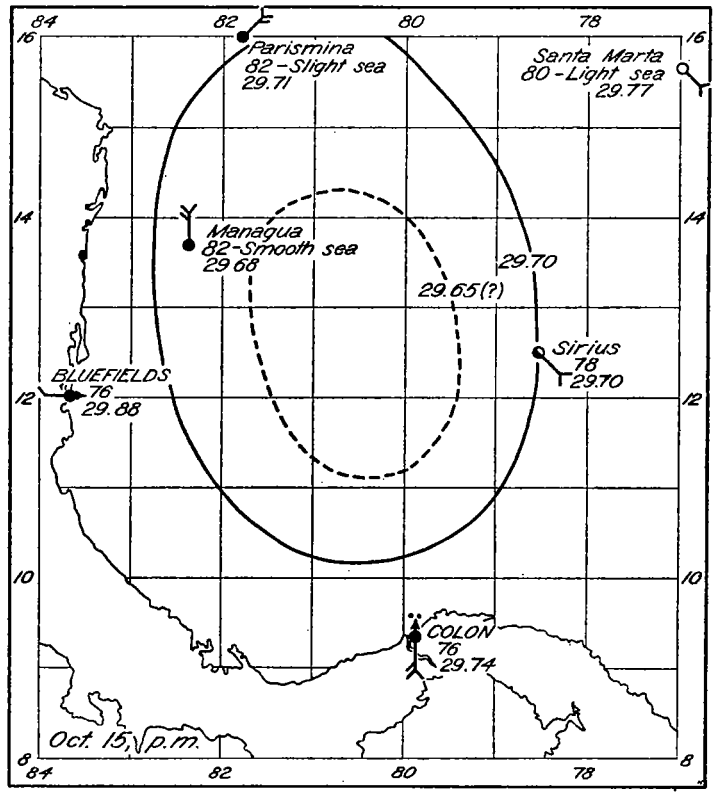

FIGURE 4.—Pressure and wind conditions at 7 p. m. of October 15, 1926

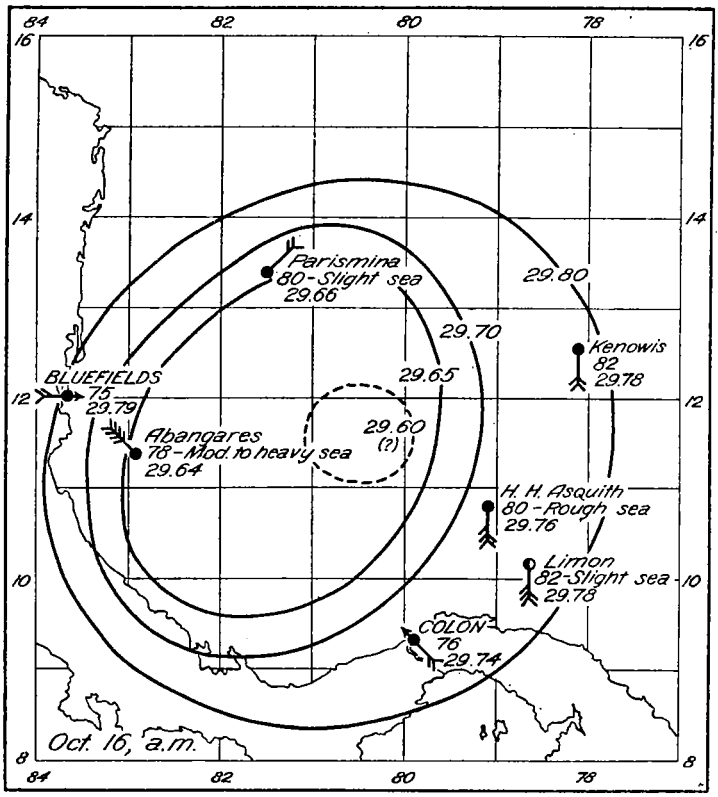

FIGURE 5.—Pressure and wind conditions at 7 a. m. of October 16, 1926

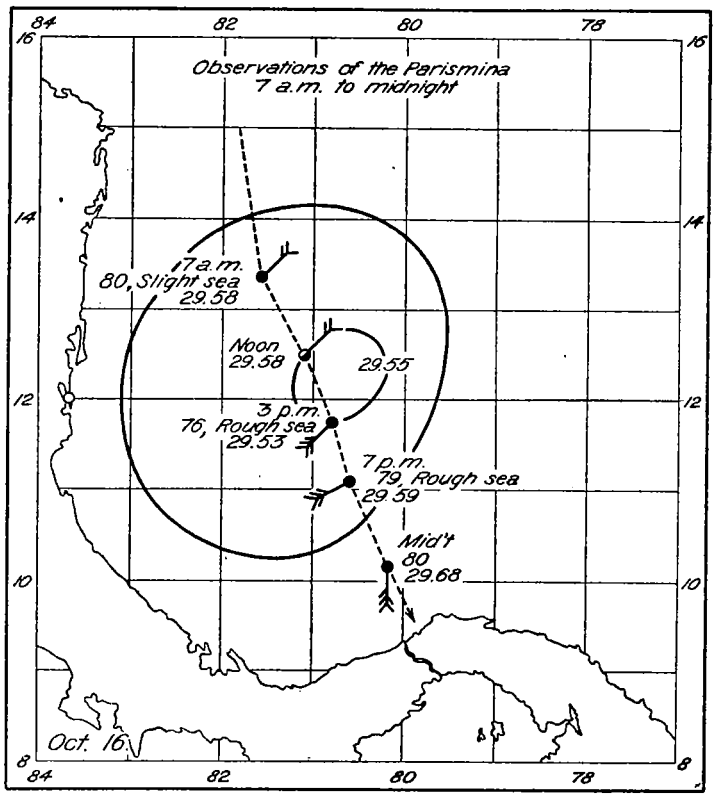

FIGURE 6.—Observations of the S. S. *Parismina*, 7 a. m. to midnight of October 16, 1926

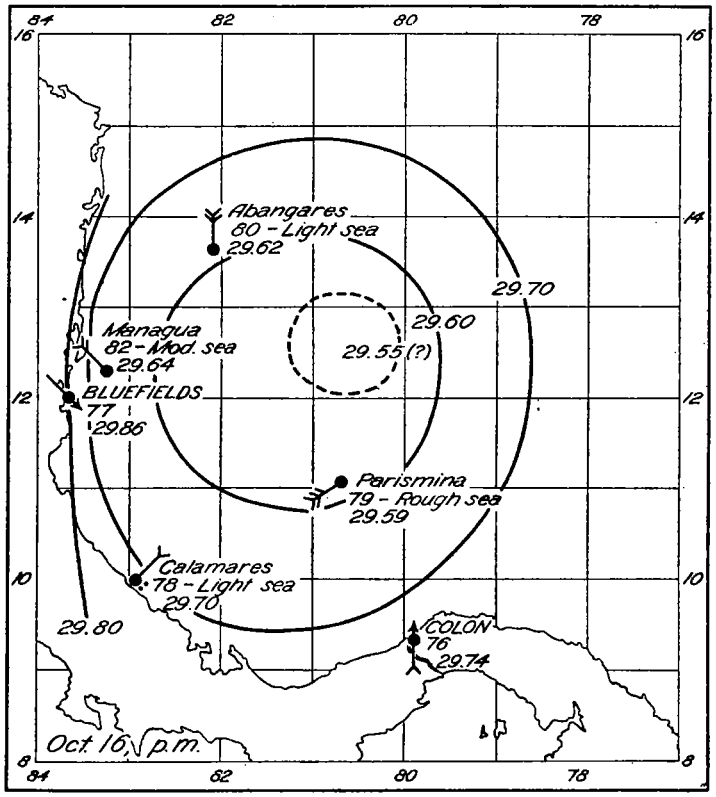

FIGURE 7.—Pressure and wind conditions at 7 p. m., of October 16, 1926

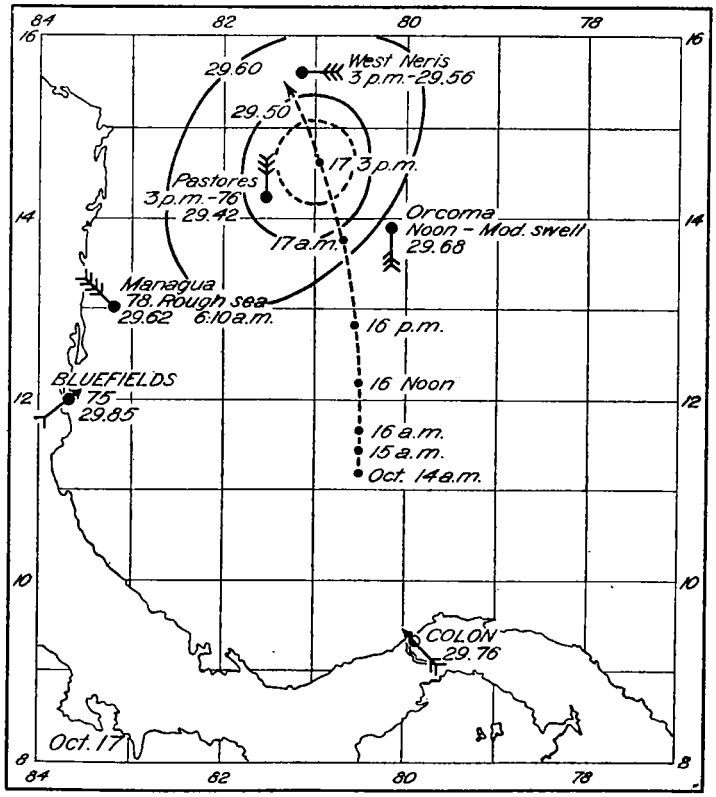

FIGURE 8.—Track of the tropical cyclone for the formative period, October 14-17, 1926, (The entire track will be found on Chart II, Monthly Weather Review, October, 1926)

begun on October 13, when a gentle cyclonic circulation was indicated by the vessel observations in that part of the Caribbean Sea already described as adjacent to the Isthmus of Panama. On the following day a small but general fall in pressure was noted as having occurred over the same area. The normal pressure over this region for the hour of 7 a. m. (seventy-fifth meridian time), at which hour the morning vessel observations are taken for the Weather Bureau, is 29.86 inches. At 7 p. m. pressure is normally slightly lower, 29.83 inches at Colon and 29.78 inches at Bluefields (Nicaragua). On the morning of the 14th the average of the station readings at these two places was 29.84 inches, 0.02 inch below normal, and that of four vessels in the general vicinity, 29.78 inches, or 0.08 inch below normal. The position of these vessels is shown on Figure 1.

On the morning of the 15th the average pressure at the two stations named was 29.81 inches and that of three reporting vessels 29.80 inches. By 7 p. m. of the 15th pressure at Colon had fallen to 29.74 inches, 0.09 inch below normal. At the same hour the average of the barometer readings of five vessels south of the sixteenth parallel was 29.72 inches, some 0.11 inch below normal. On the other hand Bluefields at this hour reported a pressure of 29.88, or 0.09 inch above normal, so that the gradient between that place and the center of low pressure, about 250 miles to the east-southeastward, was 0.18 inch, a significant value for the region.

While this slow fall in pressure was taking place the reports from ship and shore stations showed a gentle southerly wind at and north of Colon, while at some distance farther to the northward, about 300 miles, it was easterly and northeasterly, light to gentle as a rule. On the Nicaragua side light to gentle westerly winds prevailed. With the evidence presented by wind and pressure it required only a slight stretch of the imagination to place a weak cyclonic center somewhere to the north-northwest of Colon.

By the morning of the 16th cyclonic activity showed a further increase, pressure having fallen about 0.05 inch, and the wind had freshened about two points, Beaufort. Bluefields pressure was now at 29.79 inches, 0.08 inch below normal, while 75 miles to the southeastward the steamship *Abangarez* reported squally weather with rain; barometer 29.64 (−0.22) inches; wind NW., force 8; moderate to heavy sea. The conditions at this time are shown on Figure 5.

The strong wind movement off the Nicaraguan coast, reported at this time by the *Abangarez*, and 12 hours later by the *Managua*, is probably explained by the occurrence of local squalls. The observers on these vessels did not make any entries in the Daily Journal. The observer on the *Abangarez* described the weather at time of observation in the following Beaufort notation, *o. z p. q.* (overcast, haze, passing showers, squalls); the observer on the *Managua* entered merely, *o.* (overcast).

Between noon and 3 p. m. on the 16th the steamship *Parismina*, southward bound, passed through the western part of the cyclone area, the barometer falling to 29.53 inches (0.33 inch below normal) and the wind shifting from northeast to west-southwest. The sea meanwhile had increased to rough. The observations from the *Parismina* (fig. 4) probably represent close to the maximum conditions of intensity developed by the cyclone at that period. It is not apparent that much change in the location of the center had taken place between noon and 3 p. m. of the 16th, and the center at the latter hour may be placed close to latitude 12° 30′ N., longitude 80° 30′ W. From that time, however, there was a slow but steadily increasing movement of the center in a direction about north by west.

The next report to be received from a vessel in close proximity to the center was one from the steamship *Pastores*, the observation being made at 3 p. m. of the 17th in about latitude 14° 20′ N., longitude 81° 30′ W. At this hour the pressure at a point which could not have been far from the actual center of the depression was 29.42 inches, representing a fall of slightly more than one-tenth of an inch in 24 hours. Thus during the day elapsing between the observation from the *Parismina* on the afternoon of the 16th, and that from the *Pastores* on the afternoon of the 17th, the center of the gathering storm had advanced an approximate distance of 150 miles.

At noon of the 18th, 21 hours later, the mid-point of the cyclone had reached latitude 16° 30′ N., longitude 82° 30′ W., distant 300 miles from the place of origin, and had developed winds of force 11–12, as determined from the report of the American steamship *Atenas*. This vessel, Capt. E. W. Holmes, observer J. A. MacCabe, bound from New Orleans to Cristobal, was in the actual center of the storm at mid-day of this date. And it may be observed that Captain Holmes holds the extraordinary record of having obtained a noon position by observation of the sun when in the "eye" of a tropical hurricane.

The history of the storm subsequent to October 18 has been covered in another article (**3**) and will not be further considered here, beyond the statements that its center passed over Isle of Pines and western Cuba on the 19th and 20th, where it caused great loss of life and enormous damge to property, and thence, pursuing a northeasterly course, it crossed the Bahamas and on the 22d passed near Bermuda, where it caused the loss of H. M. S. *Valerian* and the British steamship *Eastway*, with regrettable loss of life. Between the 24th and 29th it performed an extensive right-hand loop in midocean, a feature of the hurricane that is very fully treated in the article mentioned.

The 8 charts in series presented herewith give as full details of atmospheric and sea conditions over the southwestern Carribean during the 14th to 17th as may be obtained from such regular and special weather observations as are at hand for the period. Supplementary details of observations are added to these from the weather logs of reporting vessels.

Discussion.—Of all the features associated with the development of this cyclone, possibly the most interesting and significant is that of the strengthening of the southerly winds at the Isthmus of Panama. This is well shown by the records appearing in Table 1. Inasmuch as in several other instances accelerated wind movement at the Isthmus has coincided with the early increase in intensity of tropical cyclones over the neighboring waters of the Caribbean, a relationship between the two occurrences is strongly suggested, notwithstanding the fact that similar acceleration has been lacking in some cases. It is not yet certain, however, whether the relationship, if real, is one of cause or effect. It appears fairly certain that in the case of this hurricane of 1926 a gentle but nevertheless true cyclonic circulation had become established over the Caribbean before any appreciable change in wind movement was noticeable at Colon. This points to local convection unaided—or should it be put, unimpeded—by extraneous air movement. Chapel has shown diagrammatically (1) that, on the average for the cyclones first reported south of latitude 15° N., the maximum frequency of southerly winds occurs on the second day of the storm's known existence as such. The fact that cyclones here form most frequently during October, when southerly

winds at Colon attain a maximum of frequency, would indicate that such winds are necessary in most if not all cases to cyclonic development.

At this point it will be illuminating to quote from Chapel on the relation between southerly winds and hurricane formations. He says:

> In a comparison of southerly winds at Colon with the time of hurricane formation it is noted that for storms first reported north of latitude 15° the maximum of southerly winds at Colon usually precedes the first report by one or two days; but for storms originating south of latitude 15°, or within 300 miles of Colon, the maximum usually occurs on the day of reported formation or the day following. In other words, as far as the near-by storms are concerned, a cyclonic circulation actually exists and has been identified as such before the maximum of southerly wind occurs at Colon.
>
> A comparison of all available records at Colon and Cape Mala indicates that the initial momentum of these southerly winds originates somewhere in the South Pacific, and that they extend northward with diminishing velocity, and are entirely independent of the existence of any cyclonic formation. According to fishermen and turtlers familiar with the southwestern Caribbean, the most obvious feature locally at the time of the formation of a tropical cyclone is frequently the southeast gales that persist, sometimes for several days, after the storm has passed. It would appear that the existence of a following wind in the wake of the moving storm, but distinct from the cyclonic circulation itself, is a reality, and that the influence of this wind in intensifying the already existing southerly winds over the Isthmus of Panama produces the comparatively high velocities which is their most noticeable feature.

The normal southerly winds at Colon are essentially light, 7 miles an hour on an average for a considerable term of years. The actual average hourly velocities at this place for October 13, 14, and 15, 1926, in advance of the onset of the stronger winds, were 5.8, 7.8, and 7.4 miles, respectively, or exactly 7 for the period. Inasmuch as fully developed cyclones form here on an average of only one every other year, it is apparent that the seasonal condition of light southerly winds must be very completely established and maintained for some time as an antecedent requisite.

In our specific case an advance of the northeast trades on a broad front at any time prior to October 15, such, for example, as occurred in October, 1930, would most probably have broken up the cyclone structure then in existence. On the other hand the fortuitous arrival of a narrow current of equatorial air that had found its way across the mountain barrier to the southward may have contributed the necessary impetus to the circulation.

The observed facts regarding the genesis of this hurricane may be summarized as follows: First, slightly reduced pressure and gentle cyclonic circulation over a region some 300 miles in diameter; second, a slow transition from this state to one of storm intensity, requiring at least three days to develop winds of gale force near the immediate center, although squalls formed locally within the affected area; third, a strengthening of the southerly winds at Balboa Heights, near the Pacific entrance to the Panama Canal, and distant nearly 250 miles from the point where the center was first definitely observed to be located, 24 hours before the center was observed; fourth, a slight increase in wind velocity above the 612-meter level, also before the observance of a center, at the naval air station at Coco Solo, near the Atlantic entrance to the Canal.

The increase in velocity at the Isthmus occurred first at Balboa Heights, at the greater distance from the cyclone center, and nearly the maximum velocity was reached rather abruptly on the 15th, high winds continuing until the 17th. On the Atlantic side, some miles nearer the cyclone center, there was a gradual acceleration to a well-marked maximum on the 18th. This difference in time suggests that the current of higher velocity was flowing at an angle to a line joining the two places, which would run about north-northeast from Balboa Heights. The explanation for the behavior of the wind probably lies in the topography of the Isthmus. It will be noted also that the maximum velocity at Colon was not reached until the cyclone center had traveled away from that place a distance of about 5°, or nearly 350 miles. Thus the wind velocity at Colon is shown as being, up to the 18th, in direct relation to the cyclone's energy, rather than to its distance away.

The record of pilot balloon flights at the Coco Solo Naval Air Station is regrettably marred by a gap embracing the critical dates of the 17th and 18th. This gap was occasioned by bad weather (rain) and the falling of the 17th on Sunday, on which day the morning observation was regularly suspended. It is therefore impossible to say definitely when the increase in wind movement at that place reached a maximum. It will be noted in Table 4 that the average of the velocities at the levels of 1,170, 1,350, and 1,530 meters was substantially the same as that for the lower levels of 216, 414, and 612 meters.

A point to be considered is that at the time of maximum velocity at Colon, that is, on the 18th, the direction of the wind was steadily southeast and apparently unrelated to the cyclonic circulation established to the northward. The reporting vessels, *El Lobo* and *Pastores*, 100 to 125 miles at sea, also were experiencing southeast winds, at variance with the circulation, and it is necessary on the day mentioned to go another 150 miles to the northward to find vessels within the field of the cyclonic circulation. Here are found the *Calamares*, *Limon*, *Managua*, and *San Benito* with southwest or south winds. The persistence of southeast winds after the passing of a cyclone was first brought to attention by Chapel in 1927.

Here the case must rest until additional evidence and further study can be combined to throw a clearer light on the formative processes of hurricanes in this region. A necessary step will be to examine areas of low pressure that form in the southwestern Caribbean and do not result in hurricanes; another to determine whether there are periods of accelerated wind movement at the Isthmus that do not coincide either with such low-pressure systems or fully developed storms. Data on this point are not available for incorporation in the present article.

In the initial stages of formation as here considered, the tropical cyclone is of more interest and moment to the meteorologist than to the mariner. During these stages weather and sea conditions are not yet sufficiently bad to cause concern to the latter and it therefore not surprising that observational details recorded by him are frequently meager. Therefore it may not be out of place here to emphasize the dependence of the student on the facts of observation—including details which must often have little or no apparent significance to the usual observer.

As an example of the type of weather development that may be expected in tropical seas during the early formative stages of a disturbance, the observations of a trained meteorologist during a period of unsettled weather in the Caribbean are of peculiar interest. The following quotation from some unpublished notes by L. T. Chapel will illustrate the point:

> A development of this kind from a practically clear sky was observed by the writer on October 24, 1927, from the steamship *Cristobal* bound from Port au Prince to the Canal Zone. The position was 60 to 90 miles east to southeast of the island of Jamaica. At 10 a. m. the sky was almost clear with a few scattered

cumuli motionless near the horizon. Low strato-cumulus began to appear around the ship and shortly thereafter rain began to fall, an "April shower" condition. There were probably a dozen separate showers within view of the ship at once. The showers rapidly became squalls and the clouds piled up. By late afternoon the separate squalls had coalesced and a pall of alto-stratus overspread the west, northwest, and north, apparently a sharply defined cloud mass 25 to 30 miles in diameter and perhaps more, with heavy rain general. The wind was light easterly throughout except when a rain squall passed over the ship.

Following are additional details of observations of the hurricane of 1926 from the weather logs of reporting vessels:

WEATHER AND SEA CONDITIONS

October 14, 7 a. m.

Calamares.—Clear, no clouds; light NW. sea.
Cartago.—Cloudy, passing showers; 5 Cu., NE.; light NE. sea.
Harold Walker.—Overcast, squalls; 9 Cu. N., SE.; smooth (NW.) sea.
San Benito.—Cloudy; 6 Cu. and Ci. Cu., NE.; slight E. swell.

October 14, 7 p. m.

Abangarez.—Overcast, squalls; 9 A. S., W.; smooth sea.
Cartago.—Overcast, rain; 8 N., NE.; light NE. sea.
San Benito.—Overcast; 10 Cu. and Ci. S., E.; slight NE. swell.
Santa Marta.—Cloudy to overcast; 8 Cu. N., SW.; moderate SW. sea.
Tivives.—Cloudy; 7 Cu. N., SW., small W. sea.

October 15, 7 a. m.

Kermit.—Cloudy; 6 Cu., SSW., slight sea.
James McGee.—Cloudy, passing showers; 8 N., var.; slight sea.
Managua.—Cloudy; 3 Cu., E.; smooth (E.) sea.
Santa Marta.—Cloudy, passing showers; 7 Cu. N., SE.; light SE. sea.
W. M. Irish.—Clear to cloudy; 4 A. St., SW.; moderate SW. sea.

October 15, 7 p. m.

Managua.—Overcast; 9 Cu., NW.; smooth (E.) sea.
Parismina.—Overcast, passing showers, good visibility; 10 Ci. S., E.; slight E. sea.
Santa Marta.—Overcast; 9 Cu. N., SE.; light SE. sea.
Sirius.—Radio report only, details shown on chart.

October 16, 7 a. m.

Abangarez.—Overcast and hazy, passing showers and squalls; 10 A. S., NW.; moderate to heavy NW. sea.
H. H. Asquith.—Cloudy with drizzling rain at times; rough S'ly sea.
Limon.—Cloudy; 5 Cu., SW.; slight sea.
Kenowis.—Radio report only, details shown on chart.
Parismina.—Cloudy, passing showers, good visibility; N. and Cu. N., ESE.; slight sea.

October 16

Parismina.—Noon, partly cloudy; light swell. 3 p. m., cloudy; rough sea.

October 16, 7 p. m.

Abangarez.—Overcast, passing showers and squalls, good visibility; 9 Cu. N., NNE.; light NE. sea.
Calamares.—Overcast, rain; 10 Cu. and N., E.; light E. sea.
Managua.—Overcast; 10 Cu., NE.; moderate E. sea.
Parismina.—Overcast with haze, rain, squally; rough sea.

October 17

Managua.—7 a. m., overcast; 10 Cu., NW.; rough E. sea.
Pastores.—3 p. m. Radio report only, details shown on chart.
West Neris.—7 a. m. Overcast, gloomy, rain; 10 Cu. N. and N., S'ly; small S'ly sea; 10 a. m., wind backed from S. to E., fresh; 4 p. m., backed to NE., strong. Experienced low barometer (29.56 inches) in latitude 15° 39′ N., longitude 81° 10′ W. (About 3 p. m., estimated.)

Special mention may be made of the singular experience of the royal mail steamer *Orcoma*, which, after overtaking and passing the gathering cyclone on October 17, while en route from Panama to Habana, was herself overtaken by the cyclone, then a fully developed hurricane, while lying in Habana Harbor on the 20th. The report of the *Orcoma* is taken from the Marine Observer, published by the British Meteorological Office, issue of September, 1927. The speed of the *Orcoma* was approximately 14 miles (statute) per hour. The weather experienced during the 17th was as follows:

4 a. m. Wind S., force 4; barometer 29.75 inches; temperature, air, 78°; overcast, frequent torrential showers; squally, with some thunder and lightning; moderate SSW. swell.

Noon. Position, latitude 13° 53′ N., longitude 80° 09′ W. (D. R.); wind S., 5; barometer 29.68; temperature 78°; overcast with rain; moderate SSW. swell.

3 p. m. Violent squall, force 10 (S.); temperature fell 4.5° before squall, rising again with passage.

4 p. m. Wind S., 6; barometer 29.53 inches; overcast with rain squalls; moderate SW. swell.

8 p. m. Wind S., 5; barometer 29.65 inches; temperature 80°; overcast with rain squalls; heavy SSW. swell.

Midnight. Wind SSW., 4; barometer 29.62 inches; temperature 79°; overcast with rain squalls; heavy SSW. swell.

NOTE.—All of *Orcoma's* barometer readings are corrected for height, gravity, and diurnal variation.

TABLE 1.—*Colon, October, 1926, hourly wind direction and velocity; hourly pressure*

Date	A. M.												P. M.												Mean
	1	2	3	4	5	6	7	8	9	10	11	Noon	1	2	3	4	5	6	7	8	9	10	11	Mid't	
HOURLY WIND DIRECTION																									
13	se.	se.	se.	se.	se.	se.	se.	se.	se.	se.	se.	sw.	w.	w.	w.	w.	w.	sw.	sw.	s.	s.	s.	s.	s.	- ----
14	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	sw.	sw.	sw.	sw.	w.	sw.	sw.	se.	s.	s.	s.	s.	s.	s.	------
15	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	sw.	s.	s.	s.	s.	s.	s.	se.	se.	se.	------
16	s.	s.	s.	se.	se.	se.	se.	se.	se.	s.	s.	s.	s.	s.	w.	sw.	s.	s.	s.	s.	s.	se.	se.	se.	------
17	se.	se.	se.	se.	se.	se.	se.	se.	se.	se.	se.	se.	s.	s.	s.	s.	s.	s.	s.	s.	s.	se.	se.	se.	------
18	se.	se.	se.	se.	se.	se.	se.	se.	se.	se.	se.	se.	se.	se.	se.	se.	se.	se.	se.	se.	se.	se.	se.	se.	------
19	se.	se.	se.	se.	se.	se.	se.	se.	se.	se.	se.	se.	se.	se.	se.	se.	se.	se.	se.	se.	se.	se.	se.	se.	------
20	se.	se.	se.	se.	se.	se.	se.	se.	se.	s.	s.	sw.	w.	nw.	nw.	nw.	nw.	nw.	nw.	nw.	nw.	nw.	nw.	nw.	------
HOURLY WIND VELOCITY, M. P. H.																									
13	3	2	4	4	4	5	5	5	7	6	7	11	13	10	5	4	5	5	7	5	4	6	6	6	5.8
14	8	6	5	5	6	5	5	7	8	11	13	10	9	10	13	7	8	9	8	7	8	7	5	6	7.8
15	5	5	6	6	5	6	5	5	7	6	7	10	11	11	4	2	3	8	8	9	12	12	13	12	7.4
16	12	12	11	12	11	9	8	11	12	11	12	11	15	16	16	12	8	8	5	7	7	8	8	7	10.4
17	7	12	13	14	16	13	15	12	16	17	18	18	15	12	11	10	8	7	6	6	5	6	5	8	11.2
18	9	11	14	14	18	16	19	19	19	20	21	21	21	20	19	18	15	13	12	12	11	11	7	9	15.4
19	9	5	9	8	7	9	9	10	10	13	13	13	12	12	11	11	11	8	8	5	6	6	5	4	8.9
20	5	4	5	4	4	6	5	6	5	6	8	8	11	13	11	10	8	7	6	3	4	1	3	3	6.1
HOURLY PRESSURE, 29 INCHES PLUS																									
13	0.81	0.80	0.79	0.79	0.79	0.81	0.82	0.84	0.86	0.86	0.85	0.82	0.80	0.77	0.75	0.75	0.77	0.79	0.79	0.80	0.81	0.83	0.82	0.80	------
14	.79	.78	.76	.76	.77	.79	.80	.81	.83	.83	.82	.81	.78	.75	.73	.73	.74	.75	.76	.77	.77	.77	.76	.76	------
15	.74	.73	.73	.73	.74	.76	.77	.79	.81	.79	.76	.73	.71	.71	.71	.70	.71	.73	.73	.74	.75	.76	.74	.73	------
16	.71	.70	.68	.69	.70	.71	.73	.74	.76	.76	.75	.72	.70	.68	.67	.67	.69	.70	.71	.74	.75	.75	.74	.73	------
17	.71	.69	.68	.68	.70	.71	.74	.77	.78	.79	.78	.76	.74	.71	.70	.71	.73	.74	.76	.78	.79	.79	.79	.78	------
18	.77	.76	.76	.75	.75	.79	.81	.83	.85	.83	.81	.80	.77	.74	.72	.72	.74	.76	.78	.80	.81	.81	.82	.81	------
19	.80	.79	.78	.77	.78	.79	.80	.82	.83	.84	.83	.80	.78	.75	.74	.72	.72	.72	.75	.77	.80	.82	.83	.82	------
20	.81	.79	.78	.76	.77	.79	.81	.82	.84	.85	.83	.81	.78	.75	.72	.70	.72	.76	.70	.78	.80	.82	.82	.81	------

TABLE 2.—*Balboa Heights, Canal Zone, October, 1926, hourly wind direction and velocity; hourly pressure*

Date	A. M.												P. M.												Mean
	1	2	3	4	5	6	7	8	9	10	11	Noon	1	2	3	4	5	6	7	8	9	10	11	Mid't	
HOURLY WIND DIRECTION																									
13	nw.	nw.	nw.	nw.	ne.	ne.	ne.	ne.	ne.	ne.	e.	se.	s.	s.	nw.	nw.	nw.	nw.	nw.	nw.	n.	ne.	ne.	ne.	
14	ne.	ne.	ne.	ne.	ne.	n.	n.	n.	n.	n.	ne.	ne.	se.	se.	s.	sw	se.	s.	s.	sw.	s.	sw.	s.	s.	
15	s.	s.	sw.	w.	sw.	sw.	sw.	sw.	s.	sw.	sw.	s.	s.	s.	s.	sw.	s.	s.	s.	s.	s.	s.	s.	s.	
16	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	sw.	sw.	s.	s.	s.	s.	
17	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	
18	s.	s.	s.	s.	s.	se.	s.	s.	s.	se.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	
19	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	se.	se.	s.	se.	se.	se.	se.	se.	ne.	ne.	
20	ne.	ne.	ne.	ne.	ne.	ne.	ne.	ne.	ne.	ne.	ne.	se.	se.	se.	se.	se.	se.	se.	se.	se.	ne.	ne.	nw.	nw.	
HOURLY WIND VELOCITY, M. P. H.																									
13	2	2	3	4	2	6	4	6	7	5	5	5	7	9	3	3	2	3	2	2	4	7	6	3	4.3
14	6	6	7	4	3	2	3	2	1	3	5	5	5	8	8	2	4	7	6	14	9	8	17	20	6.5
15	12	12	6	2	5	3	1	1	14	22	24	21	25	26	25	23	19	18	17	14	16	15	23	23	15.3
16	22	21	21	22	18	18	22	23	27	28	23	20	21	24	21	19	22	17	16	18	14	19	19	22	20.7
17	21	19	19	28	28	24	26	23	27	29	24	23	24	24	22	26	17	11	11	6	9	14	14	17	20.2
18	14	10	12	12	11	9	13	16	18	18	18	18	19	17	17	14	13	15	10	9	10	10	11	11	13.5
19	14	16	10	10	14	12	11	11	18	17	17	14	18	14	11	7	8	7	6	6	4	5	5	10	11.0
20	9	6	9	10	9	6	4	6	5	6	5	8	7	6	5	6	4	5	5	2	6	9	2	1	5.9
HOURLY PRESSURE, 29 INCHES PLUS																									
13	0.82	0.80	0.79	0.80	0.79	0.81	0.84	0.86	0.87	0.87	0.84	0.82	0.80	0.78	0.76	0.76	0.76	0.78	0.80	0.80	0.81	0.83	0.82	.81	
14	.79	.78	.77	.77	.78	.80	.81	.82	.84	.85	.83	.82	.78	.76	.75	.75	.76	.75	.76	.78	.79	.78	.77	.76	
15	.75	.73	.73	.73	.73	.75	.78	.80	.82	.81	.80	.78	.75	.74	.73	.74	.75	.76	.77	.78	.80	.80	.79	.77	
16	.75	.74	.73	.74	.75	.76	.77	.77	.80	.80	.78	.77	.74	.72	.71	.70	.72	.73	.74	.75	.77	.78	.77	.75	
17	.73	.71	.70	.70	.73	.75	.78	.78	.80	.82	.81	.80	.77	.75	.73	.72	.75	.75	.77	.80	.81	.81	.81	.81	
18	.80	.78	.77	.76	.76	.80	.82	.84	.86	.86	.84	.81	.79	.77	.75	.75	.77	.78	.79	.81	.82	.83	.84	.83	
19	.82	.81	.81	.80	.80	.81	.83	.84	.86	.85	.83	.81	.79	.76	.75	.74	.74	.74	.76	.78	.81	.81	.81	.81	
20	.79	.78	.75	.75	.77	.80	.81	.83	.85	.85	.82	.80	.77	.74	.72	.70	.71	.73	.76	.78	.82	.83	.83	.82	

TABLE 3.—*Wind direction and velocity at different levels, as shown by pilot balloon ascensions at the United States Naval Air Station, Coco Solo, Canal Zone, during formation of a tropical cyclone in the southwestern Caribbean Sea, October, 1926.*

	349.	350.	351.	353.	354.	355.	356.	357.	358.	359.	360.
Flight No. (1926)											
Date and hour	13th, 0630.	13th, 1500.	14th, 0630.	14th, 1500.	15th, 0630.	16th, 0630.	18th, 0630.	18th, 1500.	19th, 0630.	19th, 1500.	20th, 0630.
Surface wind, direction and velocity.	SE., 0.9.	WSW., 3.1.	SE., 2.2.	W., 3.6.	S., 1.8.	SE., 3.6.	SE., 8.9.	SE., 8.9.	ESE., 5.4	E., 5.4.	SE., 1.3.
Air temperature and humidity.	74°, 95 per cent.	84°, 84 per cent.	76°, 96 per cent.	81°, 87 per cent.	75°, 95 per cent.	75°, 95 per cent.	76°, 87 per cent.	85°, 73 per cent.	75°, 91 per cent.	88°, 67 per cent.	74°, 95 per cent.
Pressure	29.79.	29.76.	29.77.	29.72.	29.75.	29.70.	29.77.	29.72	29.79.	29.73.	29.82.
Upper clouds	1 CiS.	2 CiS.	6 CiS N.	3 CiS N.	2 CiS.	2 CiS NE.	5 CiS NE.	4 CiS NE.	8 CiS NW.	8 CiS NW.	5 CiS NW
Intermediate clouds	2 ACu.					2 ACu NE		2 ACu NE.			
Lower clouds	6 SCu W.	4-2 Cu-SCu SE.	3 SCu NW.	¾ Cu/SCu SW.	7 SCu SW	4 SCu SW	5 SCu S	2 Cu S	1 SCu.	1 Cu SE.	2 Cu NE.
Visibility	6.	6.	6.	7.	6.	6.	6	6.	6.	6.	6.
Sun	Obscured.	Bright.	Intermittent.	Obscured,	Faint.	Obscured.	Intermittent.	Bright.	Intermittent.	Bright.	Bright.
Disappearance due to	Haze.	Bursting.	Haze.	SCu clouds.	SCu clouds.	Haze.	SCu clouds.	Fading, CiS.	Fading, CiS.	Haze.	Bursting.

Altitude of balloon		Wind																					
		Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity	Direction	Velocity
Minute	*Meters*																						
1	216	sse.	5.0	wsw.	2.1	sse.	5.0	ssw.	4.8	s.	4.6	sse.	8.3	se.	13.0	se.	7.5	ese.	9.7	ese.	8.0	ese.	4.7
2	414	ssw.	5.0	ssw.	2.5	s.	5.2	ssw.	4.0	ssw.	5.0	s.	10.6	sse.	15.8	se.	7.8	se.	11.6	ese.	5.3	ese.	3.6
3	612	sw.	4.5	sw.	3.8	wsw.	4.7	ssw.	4.2	sw.	5.8	s.	14.0	sse.	15.2	se.	8.9	se.	11.7	ese.	7.4	se.	2.8
4	801	wsw.	4.5	sw.	3.8	wsw.	3.1	ssw.	3.8	sw.	5.9	s.	13.3	sse.	14.3	sse.	10.5	se.	10.8	ese.	6.0	ese.	3.4
5	990	wsw.	4.5	------	------	wsw.	2.0	------	------	wsw.	5.8	s.	10.4	sse.	15.0	sse.	11.3	se.	10.3	se.	4.7	e.	3.8
6	1,170	w.	3.8	------	------	w.	1.6	------	------	wsw.	6.2	ssw.	10.2	sse.	16.6	sse.	10.8	se.	10.2	s.	3.0	ne.	3.4
7	1,350	w.	3.0	------	------	w.	1.4	------	------	wsw.	6.9	ssw.	11.0	s.	17.5	sse.	8.6	se.	9.5	s.	2.0	ne.	3.4
8	1,530	w.	2.9	------	------	nw.	1.2	------	------	sw.	7.6	ssw.	12.7	------	------	s.	6.4	se.	8.5	se.	1.0	ne.	3.7
9	1,710	w.	2.7	------	------	nnw.	1.3	------	------	------	------	sw.	14.3	------	------	s.	6.6	se.	8.3	------	------	ne.	3.0
10	1,890	wsw.	2.9	------	------	nw.	1.5	------	------	------	------	------	------	------	------	------	------	------	------	------	------	ne.	2.4
11	2,070	wsw.	2.5	------	------	nw.	2.0	------	------	------	------	------	------	------	------	------	------	------	------	------	------	nne.	3.7
12	2,250	ssw.	2.9	------	------	nnw.	2.9	------	------	------	------	------	------	------	------	------	------	------	------	------	------	nne.	5.7
13	2,430	s.	2.7	------	------	n.	3.4	------	------	------	------	------	------	------	------	------	------	------	------	------	------	nne.	6.3
14	2,610	sse.	2.5	------	------	n.	3.2	------	------	------	------	------	------	------	------	------	------	------	------	------	------	nne.	5.8
15	2,790	sse.	2.6	------	------	n.	3.0	------	------	------	------	------	------	------	------	------	------	------	------	------	------	nne.	6.0

Flight 352. made at 0745 on the 14th omitted.

TABLE 4.—*Weather conditions at Bluefields, Nicaragua, at a. m. and p. m. observations, October 12–18, 1926 (From Form 1001 A)*

Day and hour	Barometer	Temperature	Wind direction	Velocity	Weather	Rainfall
	Inches	°		*M. p. h.*		*Inches*
12th, a.	29.88	75	w.	4	Cloudy	.57
12th, p.	29.88	80	0.	0	Partly cloudy	.00
13th, a.	29.88	76	nw.	2	Cloudy	.53
13th, p.	29.88	81	nw.	2	Partly cloudy	.05
14th, a.	29.86	76	w.	4	Cloudy	.12
14th, p.	29.83	78	nw.	2	do	.10
15th, a.	29.79	76	nw.	6	do	.61
15th, p.	29.88	76	w.	2	do	.15
16th, a.	29.70	75	w.	10	Rain	1.47
16th, p.	29.86	77	nw.	2	do	1.00
17th, a.	29.88	75	sw.	6	Cloudy	.00
17th, p.	29.77	82	sw.	4	do	.00
18th, a.	29.86	75	sw.		do	.00
18th, p.	29.84	80	sw.	4	Rain	.07

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"SAN NICOLÁS"—THE TROPICAL STORM OF SEPTEMBER 10, 1931, IN PORTO RICO

By F. E. HARTWELL
[Weather Bureau, San Juan, P. R.]

According to the accustomed nomenclature of West Indian storms the one which raked the north coast of Porto Rico on the night of September 10 has been named "San Nicolás" from the saint's day of that date. The first intimation of abnormal weather previous to this storm was an almost perfect wide quadrant of wind directions extending from the Virgin Islands to Barbados on the morning of the 9th. The appearance at that time was that the area named was in the southwest periphery of a very wide cyclonic area. Broadcasts were immediately sent out in an endeavor to locate the center and bulletin issued from the San Juan office that morning was as follows:

Advisory 9.00 a. m.—Sept. 10, 1931.—Disturbance of minor intensity has apparently passed through Leeward Islands and is approaching St. Thomas and St. Croix and will probably affect northeastern Porto Rico before midnight. No high winds have so far been reported and the lowest pressure is 29.72 inches at St. Martin. Caution advised small shipping on east coast of Porto Rico particularly.

(Signed) HARTWELL.

Our special observers at St. Croix and St. Thomas sent the required messages and indications pointed to the path

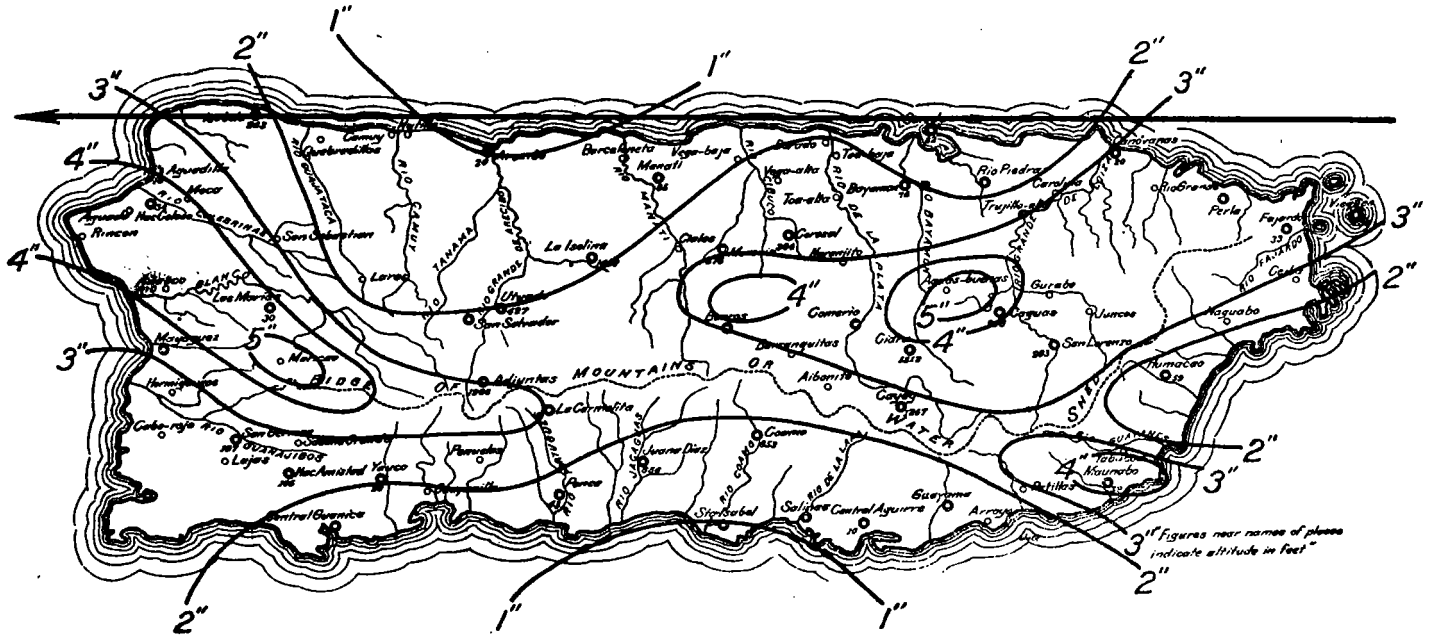

FIGURE 1.—Distribution of rainfall in Porto Rico during hurricane of "San Nicolás," September 10–11, 1931. (Arrow shows path of center)

determine its intensity, but nothing of importance was received and by evening the low area had become elongated in a north-south direction, the southern extremity apparently filling up and the northern developing into a vortex of much narrower limits than at first indicated. Nothing below 29.72 inches (at St. Martin and Antigua) was reported, and no velocities above ordinary occurred within range of reporting stations. By the morning of the 10th the center had passed through the Leewards somewhere near St. Martin and was approaching the U. S. Virgin Islands of St. Thomas and St. Croix. The slightly north of the latter station, where by mid-afternoon the storm had developed to 60 miles per hour with northwest shifting to west winds and a low pressure of 29.57 inches. By the time it had reached San Juan the intensity had increased to a low pressure of 29.17 inches and an estimated wind velocity of 90 miles per hour. This estimate is based partially upon a stop watch record made by Pan-American Airways (Inc.) officials with their 4-cup Robinson anemometer at the air field and, of course, the total mileage and the dial readings of our own anemometer.